Intraseasonal Forecasts of Tropical Cyclone Events: Transition to Operations

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LONG-TERM GOALS

The long-term goal of this project is to understand the forecastability of tropical cyclone events, which are defined to be entire tracks from formation to ending, on timescales from 5-30 days and thereby develop a probabilistic forecast technique to support the U. S. Navy and other Department of Defense (DOD) activities against the threat of tropical cyclones. Tropical cyclones are the primary weather-related threat to DOD tactical and strategic activities, and the U. S. Navy is particularly vulnerable. Developing a forecast capability on 5-30 day timescales will allow tropical cyclone event guidance to DOD activities not only to protect people and resources against the tropical cyclone threat, but also allow them to safely carry out strategic activities with confidence that there will be no significant tropical cyclones in a specific area for a stated time ranging up to 30 days.

OBJECTIVES

The first objective of this research is to document that the European Center for Medium-range Weather Forecasts (ECMWF) 32-day ensemble forecasts of tropical cyclone-like vortices in the western North Pacific can be utilized to predict tropical cyclone events on 5-30 day timescales. The metric for success is that the technique is able to predict the overall tracks of significant tropical cyclones (Tropical Storms and Typhoons) as designated by the Joint Typhoon Warning Center (JTWC). The second objective is to document the capability of the daily ECMWF 15-day ensemble forecasts to effectively update the tropical cyclone event predictions between the 32-day ensemble forecasts that are produced only on Mondays and Thursdays. The third objective is to document that the ECMWF ensemble has the capability to predict regions where there will be no significant tropical cyclone events in a specific area of interest to DOD for periods of up to 30 days, including gap periods of no tropical cyclones in the entire western North Pacific.

APPROACH

Elsberry et al. (2010) describe a technique they developed for generating “ensemble storms” from ECMWF 32-day ensemble forecasts. They provided documentation of the success in predicting on 5-30 day timescales three major typhoons during the Tropical Cyclone Structure (TCS-08; Elsberry and Harr 2008) field experiment, and for other significant tropical cyclone events during July – December 2008. Elsberry et al. (2011) then evaluated the performance of the ECMWF 32-day ensemble

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predictions during the 2009 season. Further development of the ensemble storm technique occurred as part of the support for the 2010 Impact of Typhoons on the Ocean in the Pacific (ITOP) and TCS-10 field experiments.

Elsberry et al. (2012) describe the challenges of transitioning such a research model to operational application. The first requirement is a documentation of the reliability and the limitations of the product for operational use. Some of these limitations are: (i) The ensemble storms begin too early and persist too long both over land and over the tropical oceans; (ii) More ensemble storms are predicted than exist in the JTWC best-track files, so that identification of these false alarms is a requirement; and (iii) Co-existence of multiple storms limits the predictability of the individual storms, and appears to degrade the predictability of storms in the subsequent weeks. To document the reliability and the limitations, a more comprehensive and objective validation of the predictions was required. In addition, the technique must be made more automatic and objective to generate a large data base of cases to document the reliability of the technique. For example, the production of the displays of the tracks, which were prepared for Weeks 0, +1, +2, +3, and +4 for ITOP/TCS-10, requires considerable human intervention and needs to be made more automatic. Another requirement is to calculate and display the probabilities of west-moving versus recurving tracks in bifurcation scenarios.

WORK COMPLETED

An objective track analog program has been developed to select all esnemble storm tracks predicted by the CEMWF 32-day ensemble that match the overall JTWC tracks. All ensemble storms within the allowable time difference of the JTWC track are extracted and four metrics of shortest distance, average distance, distance at formation time and distance at ending time are calculated to select potential analogs to the JTWC storm. An objective quality measure that assesses the overall track similarity between the potential analogs and the JTWC storm is calculated in terms of membership functuions for the four track metrics. Weighting factors multiplying these membership functions are adjusted to match the quality measures for the ECMWF ensemble storm forecasts in a previous subjective evaluation. Objective verifications of the ECMWF ensemble performance for the 2009 and 2010 seasons have been summarized in terms of Hits, Misses, False Alarms, and Correct Negatives that no tropical cyclone would be present in the western North Pacific.

For existing tropical storms, an objective determination of the percentages of the ECMWF ensemble member tracks that fall in eight track clusters is automatically generated from the CXML track files. In bifurcation situations, these percentages indicate the probability of a recurver track versus a west-mover (or other track types within the eight track clusters).

Access was granted for real-time ECMWF 32-day and 15-day ensemble forecasts of tropical cyclone-like vortex tracks for the western North Pacific, Atlantic, and eastern North Pacific beginning in mid-August 2012 (with access to archived tracks back to early June 2012). A chron job was written to automatically download and process the western North Pacific and Atlantic forecasts.

RESULTS

Tsai et al. (2012) developed the objective track analog and verification programs for evaluating the ECMWF 32-day ensemble forecasts of western North Pacific tropical cyclones during the 2009 and 2010 seasons.

The Week 1 through Week 4 ECMWF 32-day ensemble forecasts for Supertyphoon Megi (15W) during 2010 are selected to illustrate the objective matching of ensemble storms and the verifications in terms of quality measures. For the 0000 UTC 7 October 2010 forecast (Fig. 1a, Week 1), four ensemble storms labeled 4, 7, 9, and 12 were potential analogs with the Megi track. Ensemble storm 7 had the best match with the Megi track , but it did not include the sharp poleward turn after Megi passed the Philippines. The Week 2 forecast (Fig. 1b) initiated on 30 September was somewhat better than the Week 1 forecast in that both ensemble storms 11 and 18 begin close to where Megi formed and have tracks that cross northern Luzon, even though both forecasts then continue westward across the South China Sea rather than having a turn to the north. The Week 3 forecast (Fig. 1c) ensemble storm 20 has an exceptional track that begins close to where Megi would form almost three weeks later. Although ensemble storm 20 crosses the Philippines a little to the north of where Megi crossed, it then has a sharp turn to the north and overlays Megi's track to landfall on the China coast. Finally, ensemble storm 23 in the Week 4 forecast (Fig. 1d) is rather exceptional considering the agreement in initial positions, a period of overlapping tracks between 135ºE and 125ºE, and a turn toward the northwest late in the track. Clearly, this ensemble storm forecast should be rated as excellent.

The most important result from Tsai et al. (2012) is that the ECMWF ensemble was able to predict nearly all of the tropical cyclones in both the 2009 and 2010 seasons, and thus with only a small number of Misses that generally were short-lived tropical depressions. The contingency table summarizing the performance of the weekly ECMWF ensemble forecasts of tropical cyclones 01W through 19W during 2010 is given in Table 1. Again, the most important result is the large fraction of Hits, along with the small number of Misses. However, the False Alarms (FAs) continue to be a serious issue with a surprisingly large number (65) of False Alarms that exist in the Week 1 forecasts. Although 52 weekly forecasts were included in the 2010 sample versus only the 2 July to 31 December period in 2009, the Week 2 through Week 4 FAs are not proportionally larger during 2010. Given that 2010 was a La Niña year with fewer actual tropical cyclones, one might have expected fewer FAs. Another factor to be considered is that the horizontal resolution of the ECMWF ensemble was increased prior to the 2010 typhoon season. Another important result during 2010 was the large number of Correct Negative (CN) forecasts. Because the 2010 season had one of the fewest number of tropical cyclones in recent history, it is considered important that the ECMWF ensemble model was also able to predict the no-tropical cyclone periods as well.

Although the application is to tropical cyclone-related impacts on hydrology, Tsai and Elsberry (2012) describe a three-tier approach to provide warning support via extended-range forecasts twice weekly on the 30-day timescale, twice daily on the 15-day timescale, and up to four times a day with a consensus of high-resolution deterministic models. The benefit of such an extended-range outlook tunneling down to six hourly forecasts is to provide the longest possible seamless warning system for the threat of tropical cyclones to DOD activities.

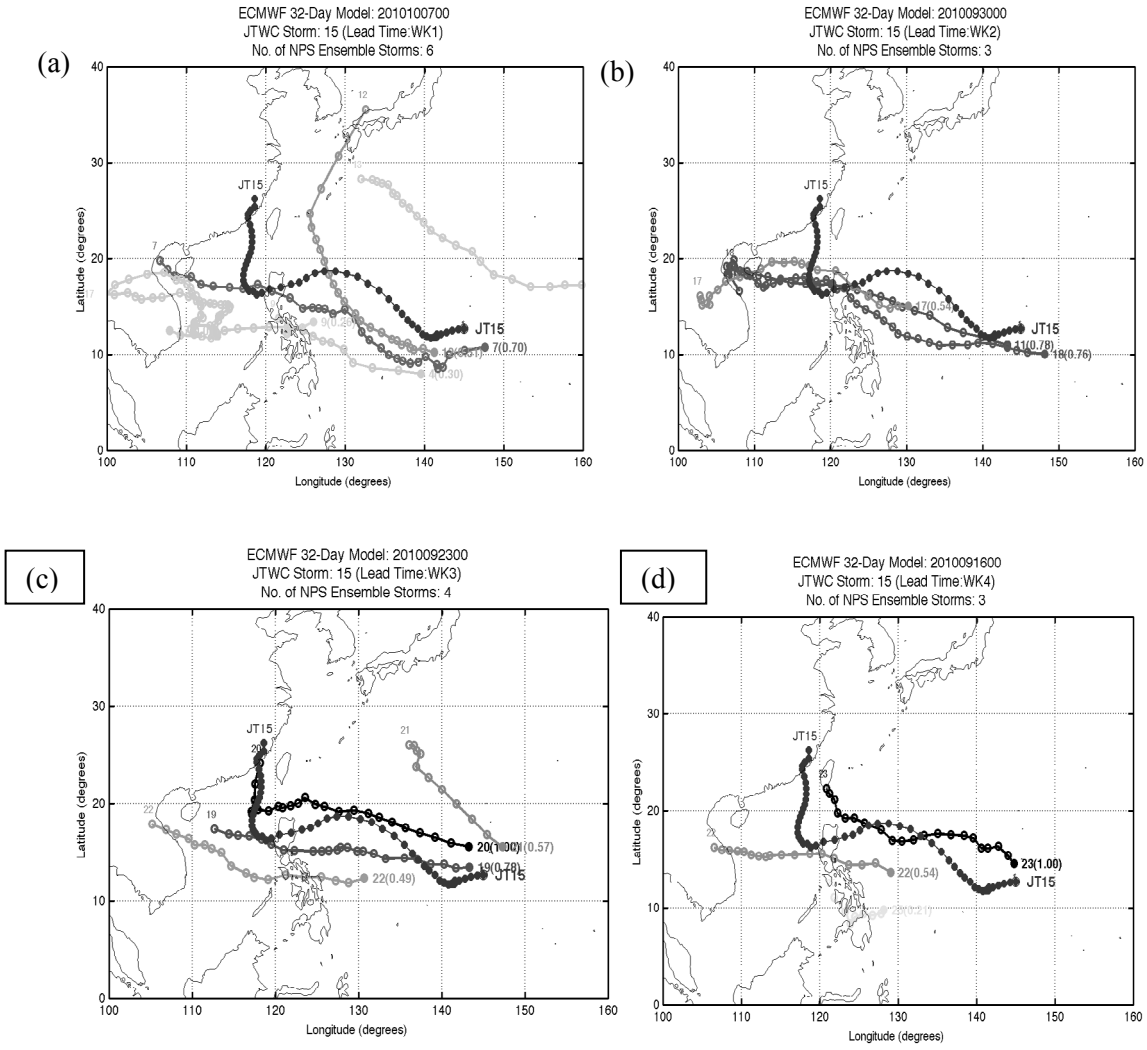

Fig. 1. Ensemble storm tracks (gray lines with 12-h positions indicated by dots) that the typhoon analog program matched with the track of Typhoon Megi (labeled JT15) for the ECMWF 32-day forecasts initiated (a) Week 1, (b) Week 2, (c) Week 3, and (d) Week 4 prior to the formation of Megi. That is, the initial times are at 0000 UTC on 7 October, 30 September, 23 September, and 16 September 2010, respectively. The matched ensemble storm numbers and the overall track likelihood value (LHV) that is used as a quality measure are given at the beginning of each track.

Table 1. Contingency table for the ECMWF 32-day ensemble forecasts for tropical cyclones 01W through 19W during 2010.

	Hits	**FAs**	**Misses**	**CNs**
Week 1	19	65	1	13
Week 2	17	24	2	27
Week 3	18	54	0	18
Week 4	15	60	3	18

Evaluations of the characteristics of the false alarms indicate seasonal and geographic biases and that about 50% of the false alarms originate from the initial conditions in the model. A minimum of false alarms being created in Week 2 forecasts is attributed to the decrease in horizontal resolution in the model that occurs at day 10. A steady and nearly uniform increase in false alarms in the Week 3 and Week 4 forecasts may be attributed to net convective heating in response to persistent environmental forcing in the tropics.

IMPACT/APPLICATIONS

The research thus far on this project indicates the potential to forecast most of the tropical cyclone events in the western North Pacific on timescales of 5-30 days. Further testing is continuing during the 2012 season beginning from mid-August when real-time access was granted. If these further tests demonstrate good reliability, the technique should be ready for transition to operational testing at JTWC. This would give JTWC a unique capability in the world to provide probabilistic forecasts of tropical cyclone events on 5-30 day timescales.

TRANSITIONS

The technique to provide JTWC forecasters the percentages of ECMWF ensemble member tracks that fall in each of the eight track clusters is automatically generated for any western North Pacific tropical cyclone. These percentages are being provided on the Naval Postgraduate School website each 12 h and will be evaluated for transition to operations for the 2012 data set.

While the ECMWF 32-day and 15-day ensemble forecasts are also available in near-real time on a Naval Postgraduate School website, these "raw" forecasts include many false alarms that need to be eliminated before they are ready for consideration of a transition.

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